

# Operations Research and Analysis

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Preliminary Report 9:  
**NEXCOM's Impacts on  
En-Route Airspace**

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## **NEXCOM's Impacts on En-Route Airspace**

### **Abstract**

In this report, the authors estimate that implementation of NEXCOM may result in user benefits of about \$ 6.3 million a year in en-route delay avoidance by 2015. About \$3.0 million of this total is for high en-route operations, and \$ 3.3 million for low en-route operations. These savings are realized by more efficient flight operations, which are, in turn, facilitated through splitting of congested airspace. This is a conservative estimate. The estimate is derived by: examining traffic in the base year of 1996 and the future years of 2005, 2010, and 2015; determining which sectors are likely to need splitting, examining the likelihood of frequency depletion in the en-route airspace, and presuming that sector splitting is a method of choice for reducing airspace congestion. Of course, the benefits of reducing congestion in the airspace can only be partially attributable only to NEXCOM. Other technologies that can be used in concert with NEXCOM, such as Data Link, WAAS, ADS-B may also stake a claim to some of the benefits. However, given that NEXCOM actually provides the required frequency, when one is otherwise unavailable, it is reasonable to presume that NEXCOM deserves the majority of the benefits.

## Background

Plans are underway to modernize the current communication system by replacing the existing Air/Ground radios with digital radios, also called Next-Generation Air/Ground Communications (NEXCOM) digital radios. The National Airspace Architecture envisions that these radios, with both digital voice and data capability, could operate with the existing communication system. It is expected that NEXCOM will solve the increasing frequency depletion in high altitude sectors and at high density terminals (1).

In Fiscal Year 1996 dollars, the cost for the proposed communications architecture is expected to be \$ 1.52 billion in acquisition cost and \$ 4.44 billion in operating cost over the life of the project, extending between 1998 and 2015 (2). This will constitute a large portion of the existing capital and operating budget. FAA, then, must make a prudent and thoughtful decision, because it will be a costly one.

A basis of need for NEXCOM is the relief of frequency depletion in high altitude sectors and at high density terminals. Such relief is important because it may have a direct impact on the airspace congestion of the NAS. In continuously congested airspace, one option to reduce congestion is to split sectors (3,4). Essentially, another controller is added to move part of the former traffic. These sectors can be split to relieve air traffic congestion, but only if there exist an assignable frequency. Hence by providing an additional frequency, NEXCOM may indeed help avoid the cost of traffic delays.

How much traffic congestion is there in the airspace now? How much will there be in the future? Is there an overlap between airspace congestion and frequency depletion? How much? When can this be expected to occur? Answers to these questions have been only subjectively provided in the past. While any information is helpful, subjective information can be challenged as speculative. Moreover, subjective information is too unstable to base investment decisions of NEXCOM's magnitude.

To answer these questions, the Investment Analysis and Operations Research organization of the Federal Aviation Administration (Operations Research and Analysis Branch, ASD-430) initiated this study. To date, the study has already resulted in one preliminary report (5). Preliminary Report 4 used airspace delay as a basis for splitting sectors, and relied on simulations associated with the Tower Data Link System (TDLS) as a basis for identifying those sectors with unavailable frequencies. Since the publication of Preliminary Report 4, field visits to the FAA's Southern Region, Southern California TRACON, and teleconferences with the Great Lakes Region, Cleveland Center, and Detroit TRACON have identified a more reasonable methodology. This report is based on the revised methodology.

In this preliminary report, we first examine the need for sector splitting throughout the NAS. This is used as a basis for establishing which sectors are candidates for splitting, and what the user delay penalty is likely to be if splitting is not possible. Second, we use stratified random sampling to identify which of the candidate sectors do not have an available frequency. Third, we aggregate delays for

those sectors with unavailable frequencies, and credit NEXCOM for avoiding associated delays, since NEXCOM will provide the needed frequencies.

Throughout this study, the analysis team worked with the NEXCOM Performance Benefits Group to arrive at study parameters and to provide a working forum to review results. Air Traffic Operations, Air Traffic Requirements, Spectrum Policy and Management, NAS Architecture, Airway Facilities, Investment Analysis, Communications IPT are all member organizations of the benefits group.

## **Need for Airspace Sectorization and Delay Impact**

### **Introduction**

As a means of identifying sectors in the NAS, the Aviation System Modeling Branch (ACT-520) of the FAA's William J. Hughes Technical Center conducted simulations of the National Airspace System (NAS). The National Airspace Analysis Capability Simulation Modeling System (NASPAC SMS) was used to conduct simulations of the NAS for the years 1996, 2005, 2010, and 2015. The model is a discrete event simulation that monitors the progress of flights as they use and compete for Air Traffic Control (ATC) system resources. ATC resources include arrival and departure fixes, flow control restrictions, runways, and sectors. Delay accrues at these resources if the demand for the resource exceeds its capacity. Data describing sector geometries were taken from the February 1997 Adaptation Controlled Environment System (ACES) database and Monitor Alert Parameters (MAPS) were provided by Air Traffic.

MAPS are used to define sector capacity and were held constant through each of the future years modeled. A 1996 Official Airline Guide (OAG) was used to generate Air Traffic activity for scheduled flights and which future growth is derived. Flight trajectories were constructed from an Enhanced Traffic Management System (ETMS) file recorded from November of 1996. Several days were simulated reflecting different weather patterns in the NAS and a 1994 Terminal Area Forecast (TAF) was used to generate future year growth.

Delay was translated into measure of cost by addressing the actual airborne operating expense of a minute of delay recorded by major airlines on Form 41. These delay costs include salaries of crew, fuel used, maintenance, amortization, and depreciation of a specific airline and aircraft type. This information is recorded on a quarterly basis by major carriers to the Department of Transportation (DOT). Delay cost statistics for the second quarter of 1996 was used in the analysis.

### **Approach**

The approach used for the airspace analysis followed three steps: (1) confirm the number and type of sectors in the en-route airspace environment, (2) identify those sectors that were candidates for sector splitting and their delay impacts, and (3) validate list of candidate sectors.

The ACES data base indicated that there are a total of about 879 sectors over the continental United States. These are shown in Figure 1: Airspace Sectors in the NAS as Identified by ACES Database. In field visits to the FAA Southern Regional Office, the Southern California TRACON, and teleconferences with the FAA Great Lakes Region, we discovered that some sectors were actually administrative in nature and had no live traffic through them. With this observation, we promptly compared the list of ACES sectors with the list of sectors that actually are staffed, and the list of sectors that are reported by the field facilities. As a consequence, we discovered that the continental United States actually has 732 sectors and corrected the ACES sector number.

“Establishment and validation of En Route Sectors,” FAA Order 7210.46 provides the underpinning for identifying those sectors that would be candidates for splitting. All field facilities, Air Route Traffic Control Centers (ARTCC’s), are required to complete an annual review and validation of sectors in their airspace. The Order focuses on two measures: sector density and sector complexity (6). Sector density is a measure calculated by multiplying an aircraft’s flight time (in minutes) through a sector by the sector’s peak hour aircraft count and dividing by 60. Sector complexity is a measure derived through an assignment of point values for each aircraft on the basis of functions, including departure, arrival, en-route requiring control function, emergency, special flight, coordination. A sector is validated on the basis of function performed, traffic volume and density, operational complexity, and traffic flows. Proposed sectors must exceed: 85 to 90 percent of the average density of sectors in the parent center. Written justification is necessary for all sectors having a density value less than 70 percent of the average density for all the sectors. Most Centers report data on sector density and sector complexity. Because sector density was easily modeled, not requiring a judgement about each aircraft’s function and because there is some relationship between density and complexity, we chose density as a basis of candidacy for splitting.

According to the latest annual sector review for each of the 22 ARTCC’s, the criteria of 130 percent sector density might serve as a criterion for splitting, or creating, a sector. We know that a density value of 70 percent is the floor value for justifying a sector. In fact, ARTCC’s have to justify sectors with less density or eliminate the sector. If 30 percent below average sector density is a floor, we presumed that 30 percent above average sector density might be a reasonable ceiling. That is, we assumed that if a sector had a density greater than 30 percent of the average sector density, it would be a candidate for splitting. This reasoning was affirmed when we discovered that Indianapolis ARTCC on October 22, 1997 requested permission to expand from five areas of specialization to six, and that request was granted (7). The density for the areas of specialization, could be reduced by as little as 14 percent and by as much as 30 percent. The request was approved by FAA Headquarter’s Air Traffic Operations.

Congestion was understood to occur when traffic flows exceed the capacity of the sector for extended periods of time. A sector was considered congested if its Monitor Alert Parameter (MAP) was exceeded continuously over 15 minutes or longer, and repeatedly over the course of a day. It was during this periods that airspace delays were accumulated for aircraft entering a sector. MAPS were provided by the Air Traffic Organization and were used as sector capacity for each of the sectors modeled.

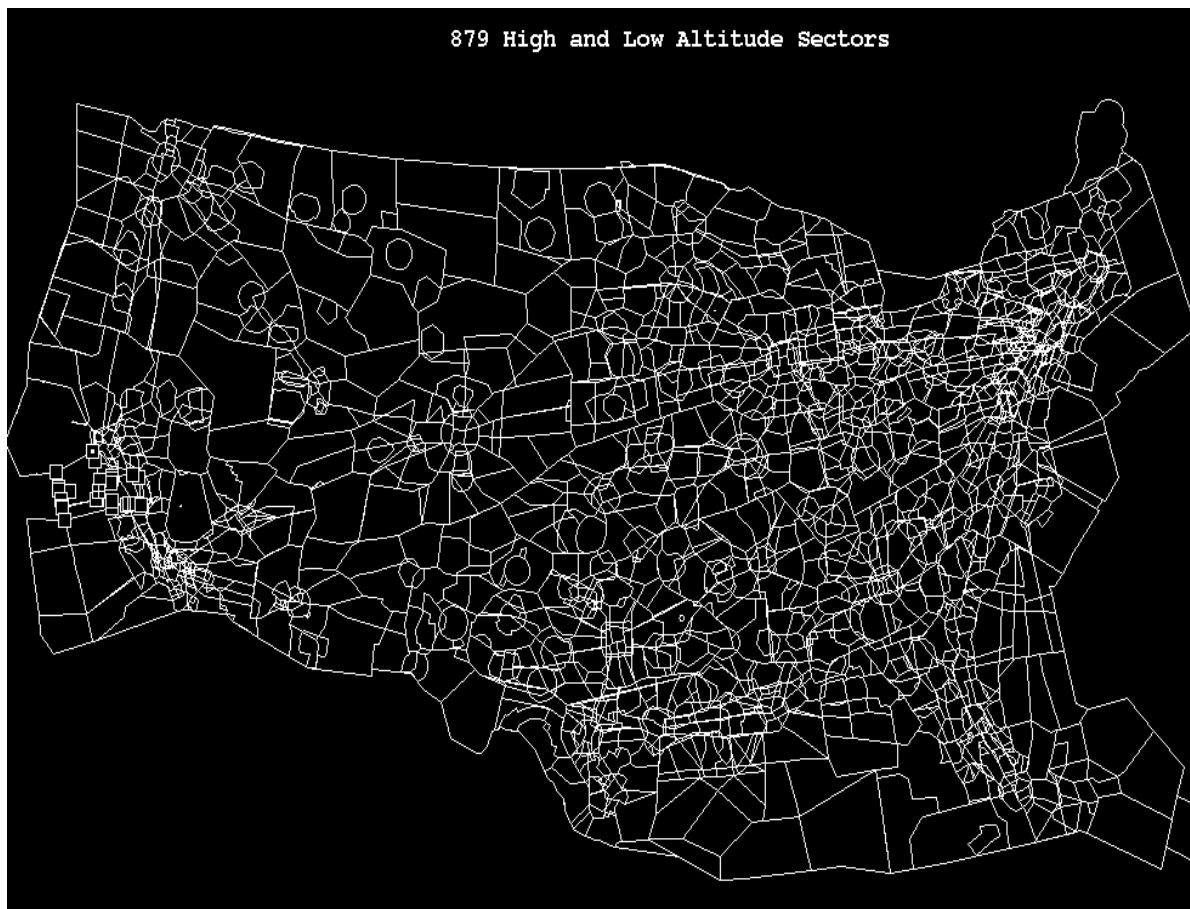


Figure 1:  
Airspace Sectors in the NAS as Identified by ACES Database

## Methodology

We conducted seventy-two simulations to identify sectors that were candidates for sector splitting. Each scenario consisted of three different Enhanced Traffic Management System (ETMS) files, in which the routes are constructed, six historical days representing different weather patterns in the NAS, and four different time frames (1996, 2005, 2010, and 2015). Since the ETMS data are used to develop route trajectories, it was important to vary this input as a means of capturing Air Traffic Control intervention. Adverse weather and demand dictate when altitude changes, speed adjustments or vectors are needed to keep flights separated. This information provides the model with detailed position reports of all IFR scheduled and unscheduled flights and is channeled through the Command Center via the 20 Enroute Centers. The model randomly assigns a flight to a specific track derived from the ETMS data.

Inclement weather is responsible for controllers delaying flights on the ground or in the air by using vectors or speed adjustments. The model captures the impacts of weather by reducing airport capacity at any affected airport in which IMC was used. Six different historical days were used as a means of varying weather patterns in the NAS for the four years modeled. We applied weighting factors to each of the six weather days in order to capture the yearly effects of weather. Future forecasts will determine which city pairs are likely to see an increase in traffic flows and thus determine which sectors will be impacted. Our analysis is depended on the growth parameters that are outlined in the TAF.

A total of 732 high and low altitude sectors were used in the study. These include enroute sectors as well as TRACON sectors. NASPAC records instantaneous aircraft counts, and flight times at sector boundaries and determines when sector capacity has been exceeded. Some flights entering saturated sectors were allowed access in order to avoid gridlock in the system. Peak hour center and sector densities were constantly calculated as the simulation ran. When the sector capacities were exceeded, delays for those sectors began accumulating and their density and delay recorded.

Cost of delay was derived by using the Cost of Delay Tool that is part of NASPAC. Airborne delay costs are a function of the Air Carrier, aircraft type, and magnitude of the delay. These costs are in 1996 dollars and are provided by the Department of Transportation's Office of Airline Statistics.

The NASPAC Simulation Modeling System keeps track of individual flights as they progress throughout the NAS, recording statistics on the country's 80 largest airports and 732 high and low altitude sectors. The model is a macro discrete simulation one in which airports are modeled on an aggregate level, while keeping track of between 61,000 (current year) and 70,000 flights (future year) in a given day. These flights consist of Air carriers, General Aviation, Military, and Air Taxi operations. Route trajectories are constructed by ETMS data, preferred routes, or great circle routes, if no information from ETMS or preferred routes exist for a given city pair. The OAG defines the schedule for a day's run. Measures of delay are then recorded as flights compete for ATC system resources. These resources include arrival, departure fixes, sectors, flow control restrictions, and airport runways. Delay accrues at sector boundaries if a flight attempts to enter a sector in which the Monitor Alert Parameter (MAP) of that sector has been exceeded. In order to avoid deadlocks in the system, flights entering sectors that have already reached their maximum capacity were allowed to enter. Delay, cost of delay, throughput, and

instantaneous counts were recorded for the 732 NAS sectors modeled. In addition, those sectors which exceeded their MAP for a duration of 15 minutes or longer were identified and examined for reasonableness.

Six of the 732 sectors, ZFW000, ZHU000, ZJX000, ZMP000, ZAB000, and ZNY000, all terminal sectors, did not have a Monitor Alert Parameter in the database. To compensate, we used a default value of 23 for the instantaneous count, as available from the ACES data base. Unfortunately with this value, the sectors exhibited abnormal delays. In the base case, the combined delay was 198 thousand hours. In the future cases of 2005 and 2010 it was 460 and 717 thousand hours respectively. We judged these delays to be unreasonably high. We believe that the Monitor Alert Parameter for these six sectors are too low. Repeated efforts to validate the MAP's for these sectors proved elusive. Rather than biasing results for delay calculations, we chose not to include these sectors in the analyses.

## **Results**

The analysis suggests that 149 sectors are currently over the sector density threshold of 30 percent over the average sector density in the parent Center. In 2005, about 152 sectors are expected to exceed the threshold criteria, including 35 new sectors. In 2010, the same number of sectors will exceed the threshold, but including only 12 sectors. Lastly in 2015, a total of 157 sectors will exceed the threshold and include 8 new sectors. In total 204 sectors, will exceed the sector splitting threshold. Figures 2 illustrates the 204 sectors exceeding the 30 percent threshold for 1997, 2005, 2010, and 2015 respectively. We label these sectors candidates for sector splitting.

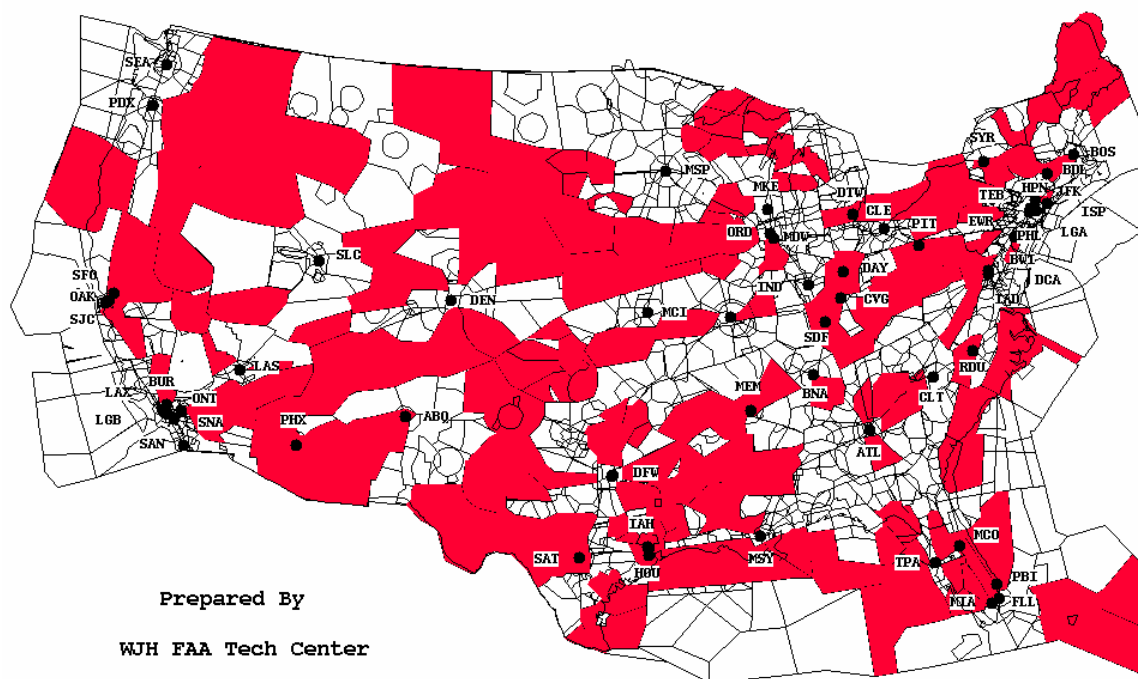


Figure 2: Sectors Exceeding Their Center's Sector Density by 30 % -- Candidate Sectors

High density in each sector implies high congestion and delays. This congestion and delay will impact the entire National Airspace System. Figure 3, shows where flights going through ZAU076 begin and end. Addressing density and congestion in ZAU076 will influence flights as far away as Seattle (SEA), Miami (MIA), Boston (BOS), and San Diego (SAN).

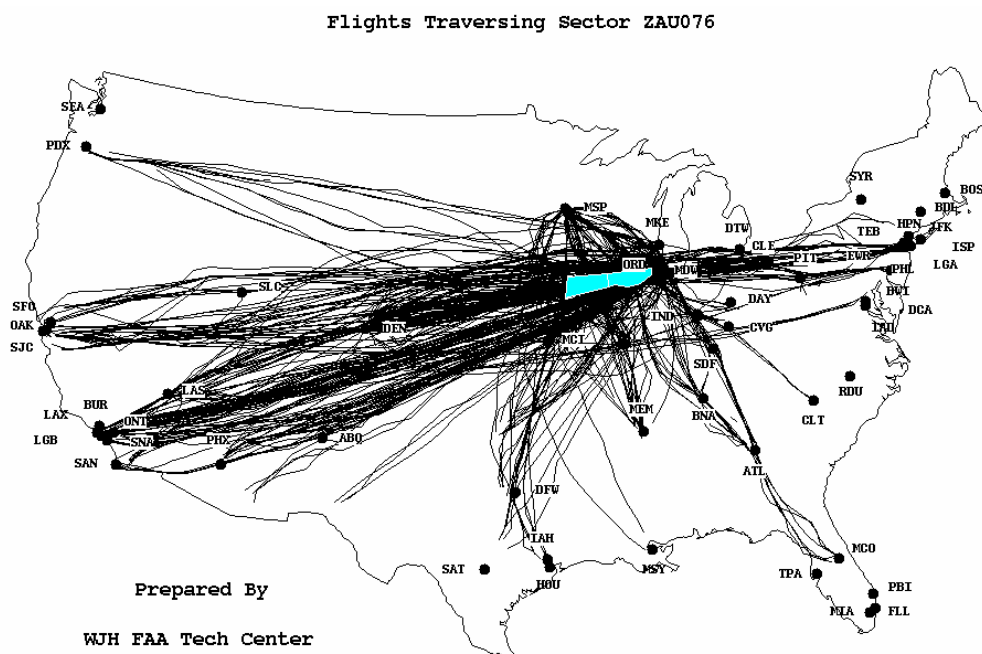


Figure 3: National Impact of Congestion in ZAU76

Sector densities and delays are explainable by understanding the character of the air traffic flow through the NAS. With some investigation, we observe that Chicago's Ohare hubbing operations were responsible for a majority of the flights that went through ZOB015, ZOB029, ZOB030, ZOB049, and a substantial amount of the traffic through ZKC066. In addition, a majority of flights traveling from the Eastern part of the United States to West Coast airports contributed to some of the congestion problems. Flights traveling through ZTL011 and ZTL043 were a direct result of the hubbing operations of Atlanta's Hartsfield airport. These flights connect most of the South with the New England Region. Most of the traffic that traversed sectors ZMA065, ZMA024 were flights connecting South Florida with the North East, Mid-West, and the Central Region of the United States. Traffic flows between West Coast airports that serve the South East and North East were the cause of most of the congestion in sectors ZLA037, ZAB038 and ZDV019.

In terms which users can understand better, since it affects their profitability, the monetary equivalent of delays through Candidate Sectors is summarized in Table 1. This table synthesizes the results for each of the four analysis years, we suggest that mitigation of airspace congestion can save significant amounts of money.

Table 1: Delays\* and Operating Costs\*\* of Delay for Candidate Sectors in the NAS

1997		2005		2010		2015	
Delays	Cost	Delays	Cost	Delays	Cost	Delays	Cost
180	\$4.3	685	\$19.6	762	\$22.7	1,930	\$60.2

\* Delays in Thousand Minutes

\*\* Costs in millions of 1997 \$

The delays in Table 1 show a large increase between the years 1997 and 2005, a small increase between 2005 and 2010, and then a much larger increase between the years 2010 and 2015. This may be due to changes in routing and schedules due to variation in growth patterns in aviation activity. The slight increase in delays between 2005 and 2010 may be attributable to a phasing in of technological improvements between these years. The large increase in delays for the 2010 to 2015 period may be due to the increase in air traffic operations without an equivalent phase in technological improvements. Moreover, the MAPS were held constant for the four years examined, and adding flights to congested sectors would increase delay exponentially in those sectors. We might expect that the cost should vary linearly in proportion to variation in delays. Indeed, this does happen. Operating costs of delay reflect the cost to operate an airline in the en-route environment. This includes such costs, as fuel, crew, depreciation and etc. In the en-route environment, we expect that the critical factor in these operating costs is the fuel cost to operate the aircraft.

Given the candidate list of sectors and the associated delay impacts, how much of this congestion and attendant costs is due to the unavailability of radio frequencies, and hence to the inability to split sectors? To answer this question, we next turn to the issue of spectrum depletion.

## Radio Frequency Availability

### Introduction

FAA's Aviation System Capital Investment Plan states that the current air/ground communication system does not have the capacity to meet short term communication demands. Of the four major problem areas, two were more noteworthy for purposes of this paper. These are: the inability to accommodate increasing numbers of sectors and services within the limited radio-spectrum bandwidth, and the inability to address air/ground radio frequency interference (4). Until recently however, frequency unavailability and interference have been treated anecdotally, rather than systematically. This

has caused much debate as to the airspace operational requirement for the Next-Generation Air/Ground Radio Communication System.

To respond to this need, we have worked with the FAA's Spectrum Planning & Internation Division (ASR-200) to fashion and apply an approach for examining the availability of radio frequency for the en-route environment of the NAS.

## Approach

While we identified 204 sectors that were candidates for splitting, it was an overbearing task to evaluate the entire set. In cooperation with Spectrum Planning & Internation Division (ASR-200), we identified a sample set of nineteen sectors on which a detail review could be conducted. We drew the set of sectors using stratified random sampling. That is, we placed each sector in one of 10 sector density strata. The 10 strata evenly divided the range of sector densities. On the basis of how many sectors were in each strata, we drew a proportional sample to be tested.

The sample set of 19 sectors was then given to ASR-200 staff and they applied the Automated Frequency Manager model to determine whether or not a frequency was available for each sector. Of the 19 sectors submitted, only 5 were found to have unavailable frequencies. We then randomly expanded this result to each strata population to project a total of 52 sectors which would not have frequency. Table 3 shows how we arrived at the 52 sector count.

Table 3: Stratified Random Selection of Sectors				
Density Stratum	Number of Candidate Sectors	Number of Sectors Chosen for Analysis	Number of Sectors with no Frequencies From ASR-200	Number of Expanded Sectors
1.3 to 1.64	157	14	5	52
1.64 to 1.98	35	3	0	0
1.98 to 2.33	11	1	0	0
2.33 to 2.67	0	0	0	0
2.67 to 3.02	0	0	0	0
3.02 to 3.36	0	0	0	0
3.36 to 3.70	0	0	0	0
3.70 to 4.07	0	0	0	0
4.07 to 4.39	1	1	0	0
Total	204	19	5	52
Total	204	19	5	52

## Methodology

The Automated Frequency Manager (AFM) model is Spectrum Planning & Internation Division's working tool for evaluating whether a facility requires a new frequency or whether existing frequencies will suffice with minor adjustments. The AFM requires such detailed information as the spatial dimensions of the proposed sector, and whether it is high or low enroute.

The AFM then applies to the proposed service volume standard frequency separation in co-channel, adjacent channel, co-site, and intermodal environments and determine if a frequency is available. The model uses the following separations:

- Channel Separation: 14dB FAC to FAC, BLOS (beyond line of site) FAB to FAC.
- Adjacent Channel Separation: .6nmi between service volumes and 25 kHz between frequencies.
- Co-site Separations: VHF (+/-) 500 kHz, 8 feet separation between transmitter antennas, and 80 feet separation between transmitter and receiver towers.
- Intermod Checks: (thru 3 signal 3rd order), Separation: FM/TV 10nmi at 50 watts power.
- Air/Ground Transmitters 1 nmi.

## Results

Out of the 19 sectors we submitted for analysis, the Spectrum Planning & Internation Division identified 5 sectors which had no frequencies available. These sectors are: ZDC 034, ZDC035, ZOB 048, ZTL 043, ZOA 32. All of these sectors were in the 1.3 to 1.64 sector density stratum, which had 14 sectors. Consequently, this implies that thirty-six percent (36 %) of all sectors in this stratum's population may have unavailable frequencies. This is about 52 of the 157 sectors, when we discount the 14 sectors already examined. These sectors were then randomly drawn and are listed below, as Table 4.

High		Low	
Sectors	Density	Sectors	Density
ZAB090	1.31	ZBW020	1.32
ZAU076	1.5	ZBW022	1.31
ZDC034	1.35	ZBW047	1.49
ZDC035	1.61	ZDC018	1.4
ZDV003	1.51	ZDC019	1.47
ZDV029	1.31	ZDV030	1.42
ZDV032	1.62	ZFW034	1.37
ZDV034	1.31	ZFW038	1.59
ZFW039	1.33	ZHU009	1.55
ZHU068	1.62	ZID035	1.3
ZHU074	1.32	ZJX028	1.45
ZID087	1.35	ZJX048	1.61
ZJX016	1.52	ZKC006	1.32
ZJX017	1.39	ZKC066	1.39
ZJX068	1.35	ZLA009	1.48
ZKC020	1.32	ZLC006	1.34
ZKC030	1.5	ZMA024	1.3
ZLA037	1.33	ZME020	1.32
ZMA065	1.5	ZME064	1.34
ZME025	1.32		
ZMP002	1.3	Total Low	19
ZMP040	1.46		
ZOA015	1.33		
ZOA032	1.57		
ZOB012	1.3		
ZOB048	1.33		
ZOB049	1.34		
ZOB067	1.31		
ZOB068	1.33		
ZOB071	1.42		
ZSE014	1.4		
ZTL011	1.37		
ZTL043	1.34		
Total High	33		

Table 4: Sectors Projected to have Unavailable Frequencies

## Impact of NEXCOM on Air-Traffic Congestion

Given the unavailability of Radio Frequency for these 52 sectors, the next step is to determine the implications on the overall delay and cost of delays.

Air traffic congestion is often abated by issuing vectors, reroutes or restrictions so that the stream of traffic is slowed down enough for a controller to safely direct traffic. In cases where sectors exhibit high sector density, there is cause for a more enduring solution, one that also strengthens safety. That approach is: sector splitting. Sector splitting is a viable option for more efficiently managing consistently dense, congested sectors. When sectors are split, the same airspace is broken down into two sectors and another controller is added to move part of the original traffic. With split sectors, and two controllers handling the traffic, congestion is relieved because aircraft are routed in a way to minimize vectoring or restrictions. However, sector splitting requires an available radio frequency for the additional controller to reach aircraft.

While not a necessary and sufficient factor to relieve congestion, NEXCOM can play a significant role. This is because NEXCOM increases the number of assignable frequencies. The availability of assignable frequencies is essential before any significant congestion mitigation action, such as splitting a sector, can be used. Such relief is important because it has a direct impact on the airspace congestion of the NAS as a whole. So, by providing an additional frequency, NEXCOM may indeed help avoid the cost of traffic congestion and attendant delays.

NEXCOM can help avoid the cost of traffic congestion and attendant delays, but only at those airspace locations where: (1) traffic congestion exists, and (2) there are no assignable frequencies to use. Both conditions must exist.

For the 52 sectors identified in Table 4, we summarize below the delays and cost of delays which an available frequency may abate.

Table 5: Airspace Delay* and Operating Cost** of Sectors without Available Frequency							
1997		2005		2010		2015	
Delays	Cost	Delays	Cost	Delays	Cost	Delays	Cost
27	\$ 0.62	84	\$ 2.54	162	\$ 5.6	187	\$ 6.3

\* Delays in Thousand Minutes

\*\* Costs in millions of 1997 \$

More detailed information from the next three figures identifies where the problems are greatest over the four analysis years. Shading intensity reflects the amount of delay. That is, the darker the shading the higher the delay. Sectors with dark shading have delays which exceed 1000 minutes per year. Lightly

shaded sectors have between 100 and 1000 minutes of delay per year. Unshaded sectors have delays of less than 100 minutes per year.

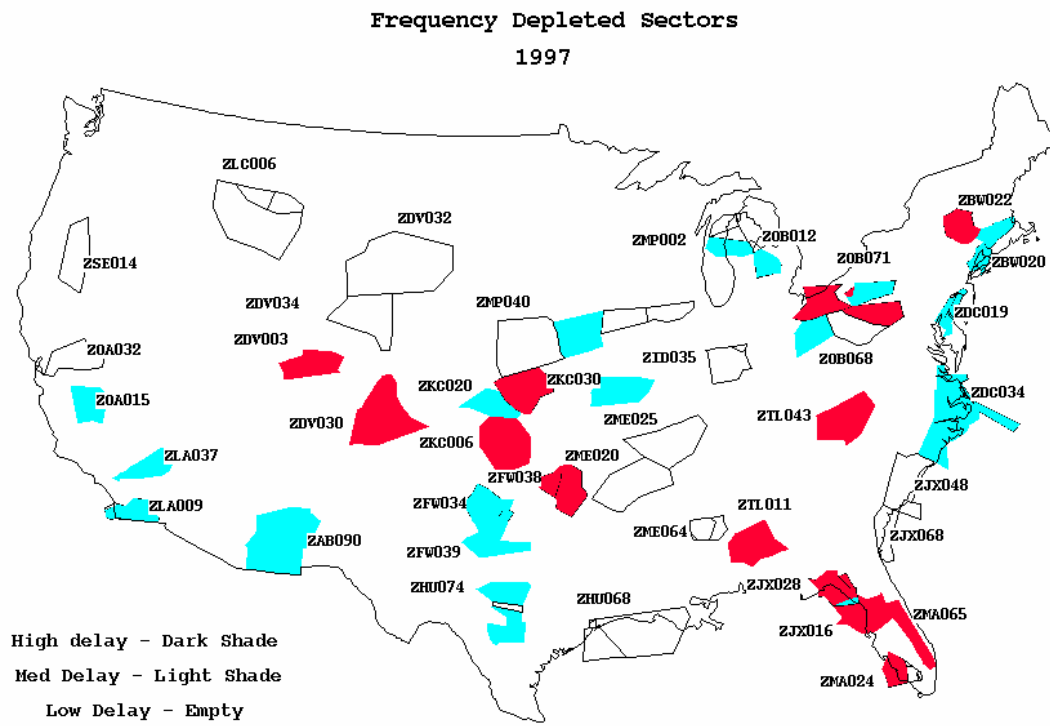


Figure 4: Intensity of Delays in Spectrum Depleted Sectors, 1997

High delay - Dark Shade  
Med Delay - Light Shade  
Low Delay - Empty

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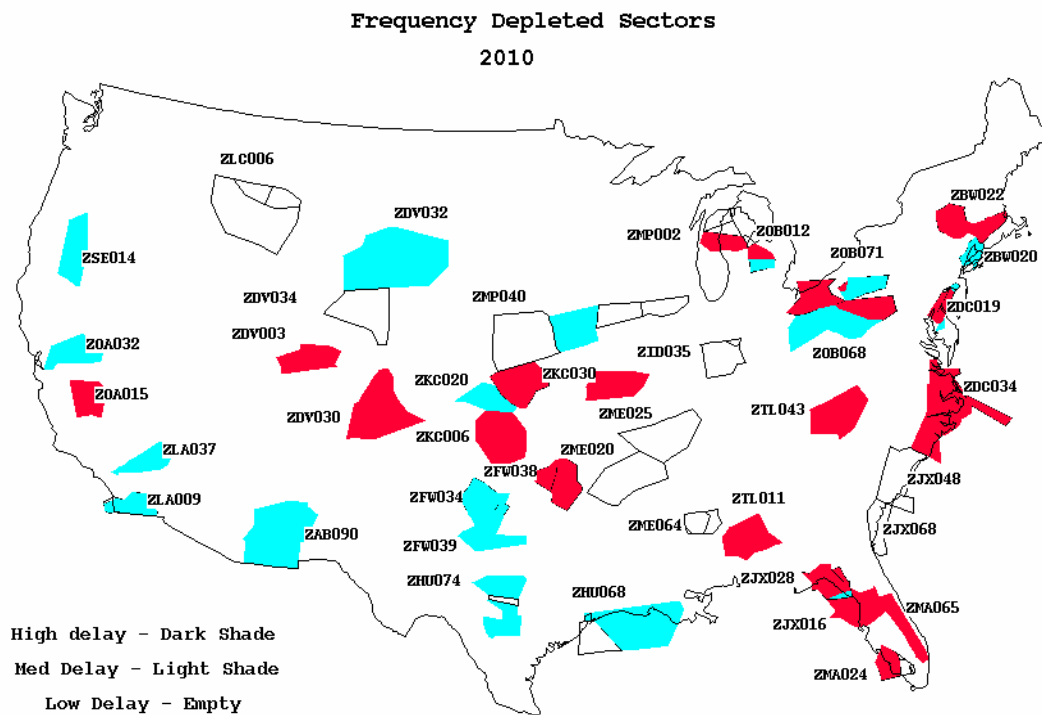


Figure 6: Intensity of Delays in Spectrum Depleted Sectors, 2010

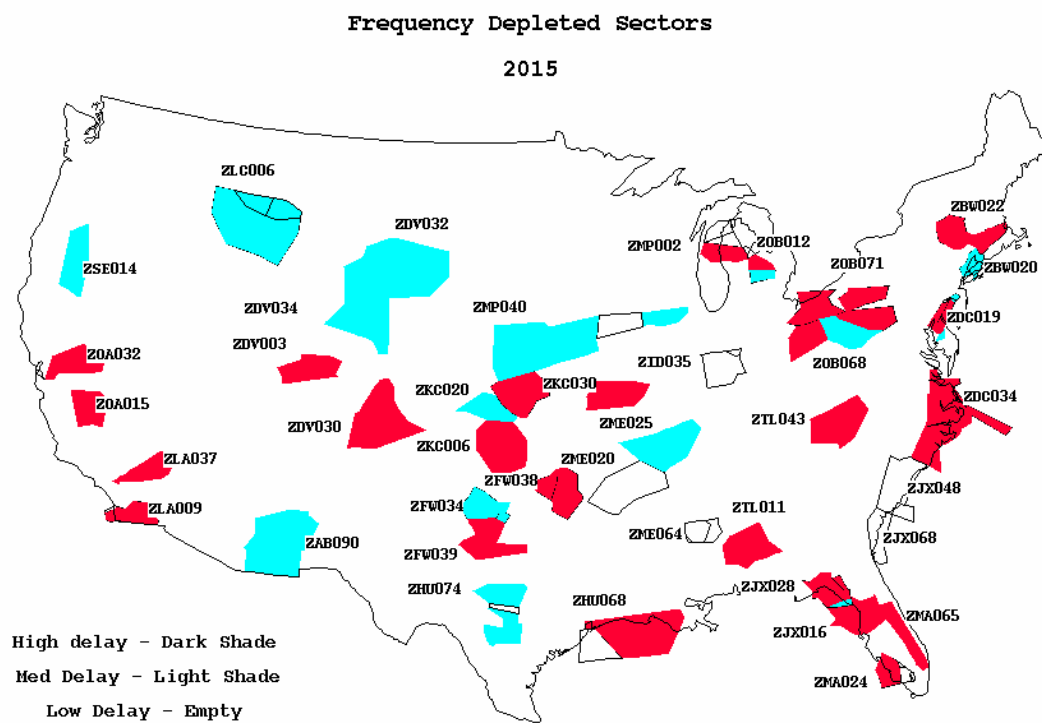


Figure 7: Intensity of Delays in Spectrum Depleted Sectors, 2015

As Table 5 shows, there are more high enroute sectors which have unavailable frequencies than Low Enroute Sectors. The specific high and low enroute sectors are identified in the Appendix.

### **Conclusions and Caveats**

We estimate that the NEXCOM Program may result in user benefits of about \$ 6.3 million a year by 2015, in avoiding delays attributable to airspace congestion in the year 2015. This is realized by more efficient flight operations, facilitated through splitting of congested airspace sectors.

The benefit of \$ 6.3 million may be a conservative estimate. It is conservative for two reasons, the full level of terminal airspace congestion and spectrum depletion could not be fully appraised. This is because Monitor Alert Parameters may be routinely exceeded in terminal sectors, and so the MAP's in some sectors may not adequately represent capacity. Also, the spectrum depletion issue can not be fully represented because of incomplete spectrum depletion data. A more precise and definitive analysis would require sector by sector evaluation of spectrum availability, rather than an evaluation of a stratified random sample of 19 sectors.

In making this estimate, we have presumed that splitting sectors is a readily convenient way of dealing with airspace congestion, and that NEXCOM will facilitate sector splitting. This connection, however, could stand more scrutiny. Are delays really reduced because sectors are split? How strong is the relationship between splitting a sector and reducing delays? Is it the most efficient way to reduce airspace congestion? The cause and effect relationship is yet to be tested. Moreover, we have presumed that sector splitting is a strategy of choice to reduce congestion. Were these presumptions relaxed, benefits would be reduced accordingly.

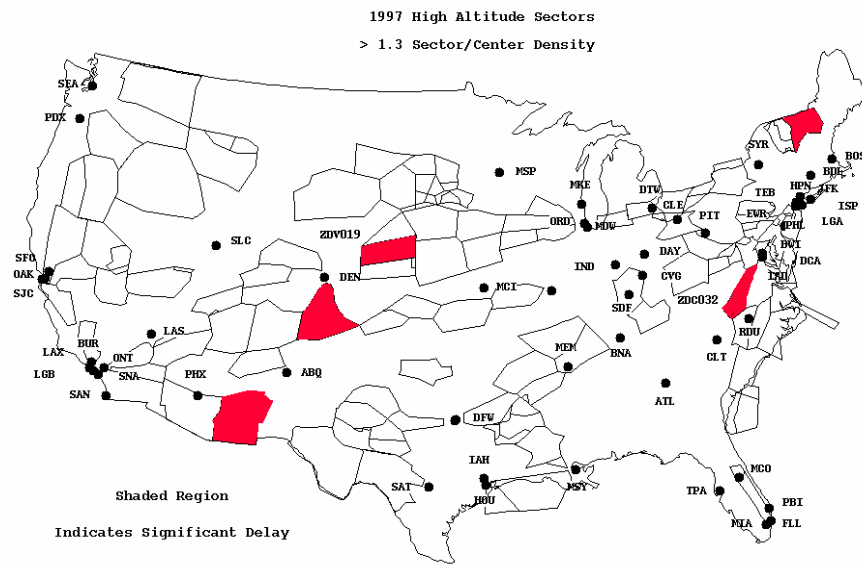
On the other hand, there may be other compelling reasons to resectorize the airspace, such as: to accommodate facility consolidation, to facilitate granting of more direct flights, to move toward dynamic free-flight, etc. These reasons would also increase the need for additional frequencies and hence for NEXCOM in frequency depleted airspace.

We should recognize, however, that the benefits of reducing congestion in the airspace can be attributable only in part to NEXCOM. Other technologies that are used in concert with NEXCOM, such as Data Link, WAAS, may also stake a claim for some of the benefits. This study only puts a bound on the possible benefits. A tighter, exclusive connection between NEXCOM frequency provision and savings in delay costs is still needed..

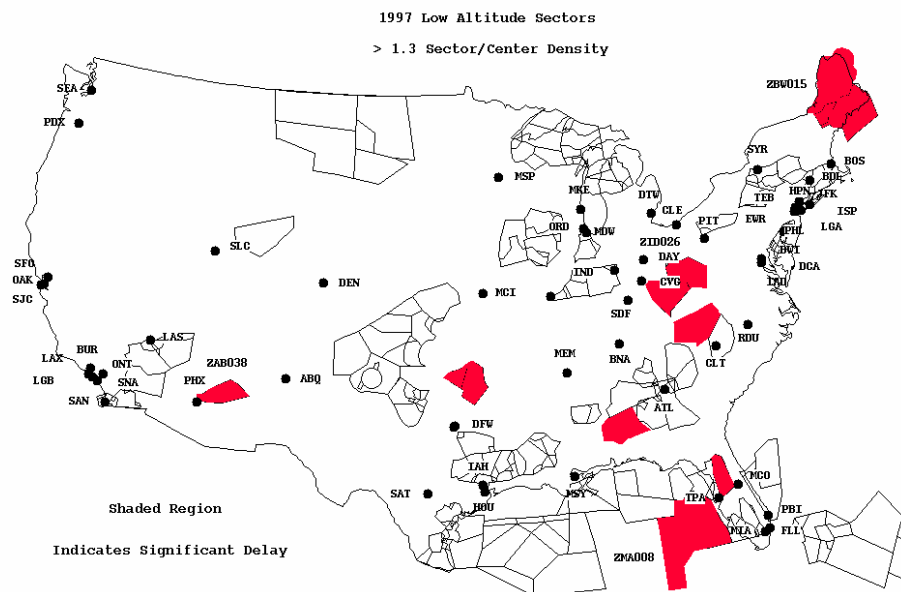
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6. Federal Aviation Administration, FAA Order 7210.46, “ Establishment and Validation of En Route Sectors”, March 16, 1984, Pages 2,3,5, and 6.
7. Maureen Woods, Manager, Air Traffic Division, AGL-500,” INFORMATION: Indianapolis ARTCC Sixth Area of Specialization,” to Program Director, Air Traffic Operations, ATO-1, dated October 22, 1997, pages 12, and 14.

## **Appendix**



**Figure A-1: High Enroute Sectors Exceeding 130 Percent of Their Center's Densities in 1997**



**Figure A-2: Low Enroute Sectors Exceeding 130 Percent of Their Center's Densities in 1997**

**Figure A-3: High Enroute Sectors Exceeding 130 Percent of  
Their Center's Densities in 2005**

**Figure A-4: Low Enroute Sectors Exceeding 130 Percent of  
Their Center's Densities in 2005**

**Figure A-5: High Enroute Sectors Exceeding 130 Percent of  
Their Center's Densities in 2010**

**Figure A-6: Low Enroute Sectors Exceeding 130 Percent of  
Their Center's Densities in 2010**

**Figure A-7: High Enroute Sectors Exceeding 130 Percent of  
Their Center's Densities in 2015**

**Figure A-8: Low Enroute Sectors Exceeding 130 Percent of  
Their Center's Densities in 2015**